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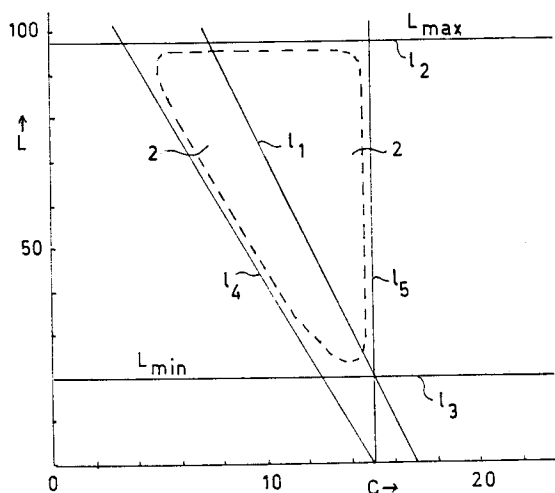
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(54) **Method of assigning a colour indication to picture elements in a colour reproduction system.**

(57) A method of selectively assigning to a picture element to be imaged with a colour reproduction system a pertinent indication relating to the distinguishing of colour in respect of such picture element. For this purpose, on the basis of the associated parameter values related to colour saturation and intensity, a choice is first made for that picture element from a pertinent indication of a colourless behaviour, a pertinent indication of colour behaviour, and a provisional indication concerning an undefined colour behaviour. In the case of a picture element having a provisional indication, this indication is then converted to a pertinent indication on the basis of the results of an environmental analysis concerning the distribution state of parameter values related to the colour space in respect of picture elements occurring within an environment of the associated picture element. According to this method, pastel hues can be reproduced in a logical and perceptually acceptable manner despite the presence of scanner noise.

**Fig.1****EP 0 593 114 A1**

The invention relates to a method of assigning a pertinent indication in respect of colour behaviour to a picture element to be imaged with a colour reproduction system. The invention also relates to a colour reproduction system provided with means for generating colour information point by point, and provided with a picture processing and control unit for correcting and processing this colour information to give control signals for controlling a colour printing unit, said picture processing and control unit being adapted to perform such a method. In the reproduction of coloured information on information supports in a colour reproduction system, the problem arises as to the way in which pastel hues can be reproduced in a perceptually acceptable and yet economically viable way.

In proportion as the degree of saturation of a pastel colour decreases further in respect of a picture element to be reproduced, at some time a point will be reached at which it is perceptually no longer logical to reproduce as such but, instead, as grey information, the colour information associated with such a pastel colour. This also has the advantage that only the black reproduction unit is required to operate in the colour reproduction system, and not one or more other colour printing units as well, and this means cheaper operation of the system and reduced wear therein.

The boundary line to be drawn in a colour space to obtain a transition between achromatic and chromatic reproduction of the picture information should first be determined on perceptual and technological grounds. This problem has already been addressed in US-A-2 918 523. However, in this case, for the sake of simplicity, achromatic reproduction of pastel colours has been selected, although this does not give a satisfactory result. A picture element which perceptually will be considered as colourless and which is in the neighbourhood of the said boundary may, as a result of scanner imperfections (such as scanner noise), be detected, not as colourless, but as colour-bearing, or vice versa. This occurs particularly in the case of picture elements situated close to the transition from the colourless area to the colour-bearing area in the said colour space. An additional factor to be taken into account is that the scanner noise increases in proportion as the intensity of the picture element increases. It is therefore logical to distinguish in a colour space a kind of uncertainty area which includes parts situated on either side of the said boundary and in which, because of the possible occurrence of scanner noise, a picture element occurring there may not automatically be assigned a colour behaviour or a colourless behaviour on the basis of its parameter values, but only a provisional indication concerning an undefined colour behaviour. Each picture element occurring in that uncer-

tainty area must then be subjected to a further and more detailed test to arrive at a pertinent indication in respect of colour-bearing or colourless behaviour. Distinguishing between picture elements having a pertinent indication of colour behaviour, picture elements having a pertinent indication of colourless behaviour, and picture elements having a provisional indication concerning an undefined colour behaviour, is already known from EP-A-0 395 032. In the system described there, however, the entire area of picture elements with a provisional indication is sacrificed for the elimination of register errors, a picture element becoming colourless in the case of a text picture, and having colour if a colour picture is involved. The elimination of scanner noise errors is therefore not addressed here.

Distinguishing between picture elements having a pertinent indication of colour behaviour, picture elements having a pertinent indication of colourless behaviour, and picture elements having a provisional indication concerning an undefined colour behaviour, is also known from EP-A-0 363 146 and EP-A-0 411 911, in which use is made of certain comparison criteria which, however, are tested in a space derived from the RGB colour space and defined by the maximum and minimum colour component values in respect of a picture element in such colour space.

A method of this kind requires considerable computing work. The maximum and minimum colour component value must first be determined in respect of each picture element and then a set of mathematical inequality functions must be examined to define the area that picture element forms part of. For a picture element having a provisional indication concerning an undefined colour behaviour, a pertinent indication in respect of a colour-bearing or colourless behaviour is then determined in this patent publication by reference to an environmental analysis. The environmental analysis to be performed in these conditions means comparing the number of pertinent indications relating to colour behaviour in an environment (e.g. a 5 x 5 picture element space) around the associated picture element, with the number of pertinent indications relating to a colourless behaviour, the result thereof then indicating what type of pertinent indication must be assigned to the associated picture element.

An environmental analysis of this kind, however, is intended to trace and eliminate register errors but not to eliminate scanner noise errors. The said environmental analysis also has the disadvantage that it gives unreliable results in an area of sort pastel hues, since relatively few or no pertinent indications in respect of a colour behaviour or colourless behaviour occur in such an area. In an

area of sort pastel hues this can result in rapid variations in the type of pertinent indications to be assigned to successive picture elements, although they may not be reproduced differently according to the original.

Also, in an area having soil pastel hues in which there are few picture elements with a pertinent indication, a small majority of one of the types of pertinent indications may, during the performance of the environmental analyses, cause the excess proportion of the provisional indications to be replaced by pertinent indications of the majority type, resulting in an incorrect colour impression.

The object of the invention is to provide a solution in respect of the said disadvantage relating to the fast variations in the pertinent indications, which can be designated "rapidly switching" in colour picture processing, and the invention is predicated on the principle that in such circumstances it is statistically advantageous, in underpinning a pertinent indication, not to rely or not to rely solely on pertinent indications occurring sporadically in the associated environment, but also or preferably on, for example, data which are related to directly connected measuring results or which have a close relationship thereto.

According to the invention, the method of the type described in the preamble is characterised by:

- a. locating the said picture element - on the basis of at least the parameter values of the said picture element related to colour saturation and intensity - with respect to a defined sub-space within a colour space, such sub-space being considered as an uncertainty area in respect of colour behaviour, the said colour space being defined by at least the parameters of the said type,
- b. performing - in respect of the said picture element upon locating in the said uncertainty area - an environmental analysis concerning the distribution state of parameter values, related to the said colour space, of picture elements occurring within an environment of the associated picture element, and
- c. assigning a pertinent indication to the said picture element on the basis of the said environmental analysis.

In a first aspect of the method according to the invention, a picture element located in the said uncertainty area is assigned a pertinent indication of colour behaviour if the relative distribution state of the parameter values related to colour in respect of the picture elements occurring in the said environment remains within predetermined limits and/or the average value of the parameter values related to colour saturation for the picture elements occurring in the said environment exceeds a certain threshold.

In a second aspect of the method according to the invention, a picture element located in the said uncertainty area is assigned a colour fulfilment degree which represents the expectation value of a picture element in respect of colour behaviour, and which can be based on an angle information, to be determined in the LC colour sub-space, associated with a straight line passing through the co-ordinate pair in that space representing the picture element and a predefined point in that space. In these conditions a picture element having a provisional indication is given a specific pertinent indication if the average value of the fulfilment degree in that environment is situated in the value area associated with that specific pertinent indication. Advantageously, the environmental analysis is based solely on those picture elements to which a partial colour fulfilment degree is assigned. It is also possible to make the pertinent indication of a picture element dependent on the total value of the colour fulfilment degree of the associated picture element and on a specific fraction of the average value of the colour fulfilment degree in that environment.

An extremely favourable use of the method according to the invention to eliminate scanner imperfections is obtained by either beforehand or simultaneously first eliminating the influences of the systematic errors, such as register errors, caused by the scanner. Since these are very disturbing at black-white transitions, as in the case of text, a test is carried out by reference to the original colour information in respect of each picture element whether such picture element has such a transition and in that case a picture element of this kind is assigned a pertinent indication of colourless behaviour. Many solutions are known for the detection of black-white transitions. As a criterion, for example, a transition of this kind is present at a picture element under investigation if a considerable brightness transition occurs around such picture element and such picture element is situated in an area of low colour saturation.

According to the principle of the invention as described, the picture processing and control unit in the colour reproduction system of the type described in the preamble is also provided with:

- a. memory means with positional data concerning a defined sub-space within a colour space, such sub-space being considered an uncertainty area in respect of colour behaviour, the said colour space being defined at least by parameters related to colour saturation and intensity,
- b. selection means for selecting a picture element having positional data within the said uncertainty area by means of the said memory means,
- c. computing means for performing an environmental analysis concerning the distribution

state of parameter values related to the said colour space in respect of picture elements occurring within a defined environment of the said picture element, and

d. means for assigning a pertinent indication on the basis of the results of the environmental analysis performed in respect of the said picture element.

The invention will now be explained using the perceptually arranged LCH colour space, although the invention can also be applied to other related colour spaces such as the HSL or CIELAB colour space.

The invention will now be described in detail with reference to the accompanying drawings wherein:

Fig. 1 represents a mathematically based graphical distribution of the picture elements concerning their perceptually assessed colour aspects in the LC colour sub-space;

Fig. 2 shows a distribution of the picture elements represented in Fig. 1 but based on other mathematical principles;

Fig. 3 shows a picture element raster required for performing the method;

Fig. 4 diagrammatically illustrates a possible embodiment of a part of a colour reproduction system; and

Fig. 5 diagrammatically illustrates a more practical embodiment of a part of a colour reproduction system.

From perceptual observations made on colour reproductions produced by a colour reproduction system provided with a unit for scanning an original point by point and generating associated colour information, these reproductions may contain picture elements which must certainly be reproduced in colour in the reproduction process, while there are also picture elements which are logically reproduced as colourless and hence only with a certain grey value. A graphic representation of a distribution of these two types of picture elements in the LC space as a sub-space of a LCH colour space is represented in Fig. 1. In this Figure, reference l_1 denotes a parting line, to the picture elements on the left of which a colourless aspect is to be assigned, while a colour-bearing aspect is to be assigned to elements on the right of that line. The colourless or colour-bearing aspect of a picture element may be added in the form of a binary representation to the data string for the picture element.

For reasons of a perceptual nature it is also acceptable to consider picture elements having a luminance (or brightness) above a certain value ($L_{\max}$) or having a luminance below a certain value ($L_{\min}$) as colourless only. Accordingly it is logical, in accordance with these principles, to effect analysis into the colour-bearing or colourless behaviour of

the picture elements for the purposes of a correct copying process.

However, it is possible that due to scanning imperfections (such as scanner noise), a scanner attributes certain colour aspects to certain picture elements which perceptually should be considered as colourless. The converse also occurs for the same reason. In other words, Fig. 1 contains an area, denoted by reference 2, extending on either side of the parting line l_1 , in which area picture elements of this kind occur and in which the colourless or colour-bearing behaviour of a picture element as perceived by the scanner may be termed unreliable. The magnitude and situation of this area 2 can be determined empirically.

Thus the degree of colour or colourlessness of a picture element and its reliability are defined as a function of its position in the LC sub-space. The scanner noise appears to be dependent on the luminance. In the case of light hues (high luminance), scanner noise and hence the uncertainty area are greater than in the case of darker hues (low luminance). The picture elements in the LC sub-space can therefore be divided into three categories as a result of the introduction of the uncertainty area 2, namely:

- picture elements having a pertinent indication of colourless behaviour; these elements occur in the area situated to the left of the parting line l_1 not covered by area 2, and also in the area above the line $l_2 \equiv L = L_{\max}$ and in the area below the line $l_3 \equiv L = L_{\min}$,
- picture elements having a pertinent indication of colour behaviour (colour-bearing behaviour); these elements occur in the area situated to the right of the parting line l_1 not covered by area 2, and not situated above the line $l_2 \equiv L = L_{\max}$ or below the line $l_3 \equiv L = L_{\min}$, and
- picture elements having a provisional indication concerning an undefined colour behaviour; these elements are situated in area 2.

A test to be performed in this way and designated an LC-test gives a distribution of the picture elements in accordance with the three kinds of indication. The last indication is provisional because it is intended that each picture element having such an indication will be assigned one of the two types of pertinent indication after a supplementary test. Each of the said indications can technically be assigned as a specific label to the associated picture element.

Whether a pertinent indication of colourless behaviour, a pertinent indication of colour behaviour, or a provisional indication of an undefined colour behaviour should be assigned to a picture element in an initial test can be determined by means of a mem-

ory (such as a "look up table"), in which the associated indication is recorded for each pair of picture element co-ordinates in the LC sub-space. This provides a rapid determination of the type of indication for each arbitrary picture element. Another possibility of determining the indication associated with a picture element is to imagine that the uncertainty area 2 in the LC sub-space is enclosed by a number of mathematically composed line elements. As shown in Fig. 1, this is possible, for example, by means of the line elements:

$$\begin{aligned} l_2 &= L = L_{\max}, \\ l_3 &= L = L_{\min}, \\ l_4 &= C = C_0 - d.L, \text{ and} \\ l_5 &= C = C_1 - e.L. \end{aligned}$$

Here, C_0 and C_1 are suitably selected constants and d and e are suitably selected direction coefficients.

A picture element having the co-ordinate pair (L, C) is then assigned the provisional indication of an undefined colour behaviour if all the following conditions are satisfied:

$$\begin{aligned} L &< L_{\max}, \\ L &> L_{\min}, \\ C &> C_0 - d.L, \text{ and} \\ C &< C_1 - e.L \end{aligned}$$

A picture element is assigned the pertinent indication of colour behaviour if the following conditions are satisfied:

$$\begin{aligned} L &< L_{\max}, \\ L &> L_{\min}, \text{ and} \\ C &\geq C_1 - e.L. \end{aligned}$$

The other elements receive the pertinent indication of colourless behaviour. The supplementary test for assigning one of the two pertinent indications to a picture element in area 2 can be performed as an environmental analysis, in which, in an environment of this picture element considered as the central picture element, it is possible to determine by reference to specific characteristics of said surrounding elements whether the central picture element should be assigned a pertinent indication of colourless behaviour or a pertinent indication of a colour behaviour.

A first method of processing picture information for such environmental analysis is based on the principle that a cluster of identical picture elements which actually merit the predicate "purely colourless" are - as a result of scanner imperfections such as scanner noise - nevertheless assigned colour or hue values which, apart from systematic deviations in the detection capacity, occur

stochastically around the grey value axis or L axis in the LCH space and are therefore distributed over the entire or substantially entire colour or hue range. However, the further a cluster of identical picture elements is situated away from the grey value axis and hence should increasingly be considered as colour-bearing, so a systematic contribution of a certain colour or hue value must be added vectorially to the said stochastically distributed colour or hue values. This in turn has the effect that in proportion as a cluster of identical picture elements is situated further away from the grey value axis, so the aperture angle at which a cluster is viewed from the grey value axis ($L = 0$ and $C = 0$) decreases. The standard deviation in the measured colour or hue values as a result of scanner noise will then also decrease. However, in proportion as a cluster of picture elements is situated closer to the grey value axis, there will be an increase in the standard deviation around the average colour or hue value. Thus when the standard deviation appears to be greater than a certain constant f , it may be assumed that it is apposite to assign the pertinent indication of colourless behaviour to the central picture element. Expressed as a formula, this analysis, which may be designated a "hue test", yields the following:

$$\sigma(H) > f$$

If this condition is satisfied, there is a real likelihood that the central picture element is colourless. A cluster of picture elements for such environmental analysis may, for example, consist of the picture elements of an $n \times n$ raster, e.g. a 5×5 raster around the central picture element under test. Instead of calculating $\sigma(H)$, it is possible simply to calculate the sum of the moments as constituents of the standard deviation. Expressed as a formula the following then applies:

$$\sum_i (\bar{H} - H_i)^2 > f^*$$

where H_i represents the hue value of the i^{th} picture element, $\bar{H}$ is the average hue value in this distribution, and f^* is a suitably selected constant derived from f . The standard deviation also forms a measure of the width of a normal distribution. For a normal distribution of this kind, 97% of the picture elements is situated in an area having a width equal to six times the standard deviation (6σ) and being situated around the average. On this basis, it may be assumed that if the distribution of the measured colour or hue values of a cluster of picture elements remains below the limit $6f$, there may be said to be a colour behaviour of the central

picture element of this cluster. Expressed as a formula this becomes:

$$(\Delta H)_{\max} < 6f$$

This derived criterion therefore forms a second method of processing picture element information in accordance with the principle of the invention, this being preferred to the criterion relating to standard deviation, for implementation reasons.

In a third method of processing picture element information in accordance with the principle of the invention, a supplementary requirement is included in order to make more reliable the decision as to assigning or not assigning a colourless aspect to the central picture element. For this purpose, a test must be made whether the picture elements in the said cluster around said picture element have an average colour saturation value (chroma value or saturation value) greater than a certain constant b. This yields the formula:

$$(\Delta H)_{\max} < 6f \text{ and } C\text{-mean} > b.$$

If this condition is satisfied, the central picture element is assigned a pertinent indication of colour behaviour. If, on the other hand, either of the two conditions is not satisfied, then the picture element may be said to have colourless behaviour. Another way of determining, in an LC test, whether a picture element situated in the uncertainty area should be given the pertinent indication of colourless behaviour or colour behaviour, is based on applying the principles of fuzzy logic, and is founded based on the principle that in proportion as a picture element is closer to the area of the colour-bearing picture elements such picture element in all probability has a higher degree of colour potency, which will hereinafter be referred to as "colour fulfilment degree" (COLfd). A possible development of this idea is shown in Fig. 2, in which two parting lines l_6 and l_7 are drawn in the LC sub-space along and on either side of the uncertainty area 2.

When l_6 as a parting line between the colourless area and the uncertainty area forms an angle a_1 with the negative C-axis and the intersection of l_6 and l_7 is given by (C^*, L^*) , then l_6 can be reproduced by the equation:

$$l_6 \equiv L^* - \operatorname{tg}(a_1) \cdot (C - C^*)$$

Similarly, line l_7 by:

$$l_7 \equiv L^* - \operatorname{tg}(a_2) \cdot (C - C^*)$$

where a_2 is the angle made by line l_7 and the negative C-axis. These two lines form part of a

bunch of lines which are mathematically described by $l_8 \equiv L^* - \operatorname{tg}(a) \cdot (C - C^*)$. In practice, it may be stated that: $l_6 \equiv l_4$ and $l_7 \equiv l_5$. If a picture element is situated on the left of the line l_6 , in which case, therefore, $a < a_1$, this picture element is assigned a COLfd of 0 because of the colourless character, and this therefore represents a pertinent indication of colourless behaviour. On the other hand, a picture element situated on the right of the line l_7 , and for which, therefore, $a > a_2$, is assigned a COLfd of 1 because of the colour-bearing character of this picture element. This represents a pertinent indication of colour behaviour. However, a picture element situated between the lines l_6 and l_7 and situated on line l_8 with a directional coefficient $\operatorname{tg}(a^*)$ from the line bunch, is assigned a partial fulfilment degree COLfd of $(a^* - a_1)/(a_2 - a_1)$, representing a provisional indication of undefined colour behaviour.

It follows from this that each picture element in the LC sub-space is assigned a fulfilment degree situated in the segment $[0, 1]$. In this connection it should be noted that the fulfilment degree COLfd is 0 in the case of the colourlessness of the picture elements having $L > L_{\max}$ and those having $L < L_{\min}$.

Although it is possible to calculate the associated directional coefficient a^* , and from that the COLfd value by reference to the measured L and C co-ordinates for each picture element, quicker determination of the COLfd value is obtained by means of a memory unit such as a look up table, which directly yields the associated COLfd value for each pair of L and C co-ordinates to be supplied.

Just as was the case in the previous embodiments, here again it is necessary to replace the provisional picture element indications by pertinent indications, and this is possible by two methods of processing picture element information in accordance with the principle of the invention as described in detail hereinafter.

According to a fourth method of processing picture element information, in an environment (for example a 5x5 picture element raster) around a picture element to be designated the central picture element, the average is calculated of the COLfd values of all the picture elements situated around the central picture element as far as they originally had or still have at least a provisional indication, and hence have COLfd values situated in the interval (0, 1).

Expressed as a formula:

$$\overline{\text{COLfd}} = \frac{1}{N} \cdot \sum_{\substack{i=1 \\ i \neq 13}}^{25} (\text{COLfd})_i$$

for $(COLfd)_i \neq 0$ nor 1

and N = number of picture elements with $(COLfd)_i \neq 0$ nor 1

If this average $COLfd$ value is above 0.5 or equal to 0.5, then the central picture element is assigned a pertinent indication of colour behaviour to replace its provisional indication; if, however, said average value is below 0.5, then the central picture element receives a pertinent indication of colourless behaviour.

According to a fifth method of processing picture information, an average of the $COLfd$ values is again calculated, and then a certain fraction k of this average $\overline{COLfd}$ is added to the $COLfd$ value of the central picture element (with index 13), whereafter the resulting value is normalized by a factor $1/(1 + k)$ to give an end value $COLfd^*$ to the central picture element with

$$(COLfd^*)_{13} = \frac{(COLfd)_{13} + k \cdot \overline{COLfd}}{k + 1}$$

If this end value is above 0.5, then the central picture element is assigned a pertinent indication of a colour behaviour; otherwise a pertinent indication of a colourless behaviour.

There are picture elements in the uncertainty area which, on the basis of the foregoing, are considered as colour-bearing whereas in fact they should have been considered as colourless. This concerns picture elements at the edges of black-white transitions and which, as a result of register errors in a colour scanner exhibit a colour tinge along said transitions. Register errors are the result of the fact that the separate measurements for the different colour co-ordinates R , G and B do not take place at exactly the same point as a result of the true geometry of the colour-CCD. This is virtually not striking in an even (coloured) surface, but it is at the edges in the case of colour transitions and even more in the case of black-white transitions. The latter then results in situations in which a method of processing picture element information as already discussed recognises colour at black-white edges. This type of colour behaviour should be considered a systematic deviation of the scanner process and not as a result of a stochastic process in the scanner. It is accordingly advantageous if picture elements having the picture errors due to this type of colour tinge are selected for their systematic character prior to or simultaneously with a picture element information processing method as described above, and to decide on whether or not there is a colourless behaviour in respect of these picture elements with suitable criteria, in such manner that at least as many

black-white edges with a colour tinge as possible are replaced by ideal black-white edges. Thus for each picture element it is necessary to check by reference to the original colour information whether there is such a transition present at that picture element and if so a picture element of this kind is assigned a pertinent indication of colourless behaviour. A number of methods are known for this purpose from the prior art, some of which are given in US-A-4415920, EP-A-0349780, EP-A-0369720 and EP-A-0411911. A particularly favourable method is based on the principle that there is a considerable brightness transition around such a picture element and that such a picture element is situated in an area of low colour saturation. An algorithm adapted to this comprises two steps: during the first step a check is made whether the central picture element forms part of an edge with a sufficiently strong brightness transition, and this is therefore anticipatory of the presence of a black-white transition. A check is also made as to the direction in which this edge is situated. For this purpose, in a raster of, for example, 5×5 picture elements, four standard edges with different orientations are assumed around the central picture element as shown in Fig. 3. The first edge or the 0-degree edge extends vertically through the raster; the second edge or 90-degree edge extends horizontally through the raster; the third edge or 45-degree edge extends from the top left-hand corner to the bottom right-hand corner; and the fourth edge or 45-degree edge extends from the bottom left-hand corner to the top right-hand corner. Each standard edge gives a division of the raster into two sub-rasters, and for each of the sub-rasters the maximum and minimum brightness values (or intensity values) of the picture elements occurring therein are determined. Advantageously, the picture elements situated on an edge are not included in the determination of the brightness value in such a sub-raster. Of all the standard edges, that edge is selected where the difference between the maximum brightness value of one sub-raster and the minimum brightness value of the other sub-raster is greatest.

A check is then made in respect of the selected edge as to whether the said difference between the maximum and minimum brightness value is greater than a certain boundary value g .

Expressed as a formula: $(\Delta L)_{\max} > g$

Only if that is the case the selected standard edge is considered as a potential black-white edge, since there are usually no considerable variations in luminance in the case of a colour edge transition. If the said difference is not greater than the boundary value g , the test for a black-white edge for that picture element is terminated and it is therefore assumed that this picture element does not form

part of a black-white edge. If a standard edge is considered as a potential black-white edge, the second step is started. In the second step, the average chroma value (Cmean1; Cmean2) is determined for that potential edge in each of the two sub-rasters, and from this an assessment is made as to whether there is a colour tinge present. Here again it is advantageous not to include in the determination of the average chroma value those picture elements which are situated on said potential edge. If the average chroma value of each of two sub-rasters remains below a certain boundary value h, hence Cmean1 < h and Cmean2 < h, it may reasonably be assumed that there is little or no colour present here and that the potential edge may be considered as a true black-white edge. The central picture element in question is then considered colourless (with chroma value 0). In order to obtain more certainty as to the presence of a black-white transition, the following can be tested a supplementary requirement: $|Cmean1 - Cmean2| < n$, where n is a constant. Perceptually, however, an undesirable edge black replacement in the case of colour surfaces having weak saturation and for certain colour transitions from background to colour, has no disturbing influence on the entire result. From the aspect of technical considerations, it is preferable for a picture element which is thus considered as colourless to be additively assigned a separate label (bit) and not to have it operate as a substituent of the original measured value, since this measured value may later be important for a subsequent analysis into colourless behaviour or colour behaviour of neighbouring picture elements. The picture elements which are not designated colourless on the basis of the edge black replacement algorithm should then be subjected to an analysis for colourless behaviour or colour behaviour in accordance with one of the picture information processing methods discussed in connection with Figs. 1 and 2.

Despite the use of the black edge replacement algorithm and carrying out the analysis as to colourless behaviour or colour behaviour on the picture elements, it may happen that some picture elements are nevertheless still wrongly considered colourless or colour-bearing where an opposite designation would be correct. This is because compromises must always be made in respect of the ideal processing when determining the critical values applied. In particular, in the case of black-white transitions, picture elements with a specific colour may be left over as a result of register errors. Picture elements of this kind having an incorrect classification are then re-tested with a post-processing algorithm. According to this algorithm, a picture element considered to have colour behaviour can be rendered colourless if, for example,

many picture elements having a pertinent indication of colourless behaviour occur in a certain environment of such picture element (and hence few picture elements having a pertinent indication of colour behaviour, e.g. less than 10%), and the luminance contrast is high (something which again appeals to the occurrence of black-white text in the environment of the picture element under test). The said environment in which this post-processing algorithm is operative is formed by a picture element raster which can be made fairly large, e.g. a 16x16 raster or even better 25x25 raster.

In accordance with this principle, it is logical if a picture element considered to have colour behaviour is made colourless in the case of the latter raster if the following equation is satisfied:

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$$\sum_{i=1} k_i < 63 \text{ and } (\Delta L)_{\max} > g$$

where g is a constant. Here $k = 1$ or 0 if the i^{th} picture element has colour behaviour or colourless behaviour respectively.

A favourable result is also obtained if this post-processing algorithm is carried out in a 25x25 raster with half the resolution.

Although determination of the formula

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$$\sum_{i=1} k_i < 63$$

actually involves colourless picture elements, it makes little or no difference in practice to include picture elements with colour behaviour for the sake of simplicity. This provides a saving of one picture element selection mechanism.

Instead of $(\Delta L)_{\max} > g$

an alternative criterion can be used with good results and better implementation possibilities, namely: it is necessary to satisfy the two requirements that there should be a minimum number of picture elements with a luminance above a certain high threshold and a minimum number of picture elements with a luminance below a certain low threshold. A post-processing algorithm can also be used for an operation in the reverse direction, i.e. to give an indication of colour behaviour to a colourless picture element in a substantially coloured environment in order to obtain better uniformity in the colour reproduction.

Fig. 4 diagrammatically illustrates an embodiment of part of a colour reproduction system provided

with a colour scanner or colour scanning unit 5 for scanning an original point by point and generating associated colour information.

In this, light intensity measurements are carried out by means of a scanner for every scanned point on the successive scanning lines of the original subjected to exposure, and after a number of corrective system steps and picture processing steps have been performed the measurements are suitable for conversion to control signals for the colour printing units of the colour copier, or other colour reproducing means such as a "flying spot scanner".

Scanners usable for performing the method of the invention are indicated throughout by the English term "line scanner". This does not mean that a "line scanner" must consist of a single row of light-sensitive elements. Reasons associated with manufacturing technology and financial considerations have often led to other embodiments of scanning means being developed which with some adaptation are considered suitable for measuring intensity signals line by line and for each scanned point for each desired colour component. Some embodiments of scanning means suitable for the purpose are known from GB-A-2157114, US-A-4553160, US-A-4750048 and US-A-4866512.

In principle, the "area-scanners" can also be used for performing the method according to the invention, it being possible to perform the steps according to the invention in two ways, in the case of the parallel reading out of the line arrays: on the one hand it is possible from a memory in which the read-out intensity information for each scanned point and for each colour component is first stored. On the other hand, during the reading out of the intensity information the method according to the invention can be performed by performing the method line by line in a direction at right angles to the read-out direction of the line arrays. The successively arranged line arrays thus each deliver the intensity information of a single scanned point, and this is then used to determine the white reference value for each scanned point and each colour component for the line defined by the scanned points.

Instead of scanner it is also possible to use a receiving unit forming part of a communication system (e.g. a facsimile system). The colour reproduction system is also provided with a picture processing and control unit 6 for correcting this colour information, the assessment regarding colour behaviour or colourless behaviour taking place for each picture element. The picture processing and control unit 6 is also suitable for processing colour information obtained via the correction phase in order to produce control signals for controlling a colour printing unit 7 adapted to multi-colour printing. For each picture element, the col-

our components R, G, B measured by a scanner 5 are converted to the LCH colour system in unit 8. During this conversion, the R, G and B co-ordinates are first converted to the XYZ colour space via a matrix multiplier, the matrix coefficients of which are scanner-dependent. A conversion to the CIELAB system then takes place in the manner described in R.W.G. Hunt: "The Reproduction of Colour in Photography, Printing & Television"; Fountain Press, England, 4th edition, para. 8.8. The data concerning the (white) reference point associated with the background of the original must be taken into account in this case, such data being delivered by unit 9. The conversion then takes place to the LCH colour system as described in the said book by Hunt.

The white reference point should be determined accurately, since otherwise the grey value axis will be incorrectly determined in the LCH colour system so that the uncertainty area with the provisional indications of possible colourless or colour behaviour will be incorrectly disposed in the LCH colour system with adverse consequences in respect of the colour/colourless investigation of the picture elements. Determining the white reference point is described in detail in: GB-A-1541578, EP-A-0188193, NL-A-9101301 and NL-A-9101894. Of course, when facsimile equipment is used which receives the picture information in the required colour system, the LCH system in this case, the units 8 and 9 are kept out of the operational part of the system. Information concerning the said indications relating to colour behaviour, colourless behaviour or undefined colour behaviour are then added to each picture element in unit 8. For this purpose, unit 8 comprises memory means, e.g. a look up table, with positional data defined in the LCH space in respect of the various indications concerning colour behaviour. Before the further analysis into colour behaviour is performed, a check must first be made whether the colour parameter values supplied for each picture element actually are situated within the colour reproduction space of the colour printing unit 7. If this is not so, the colour parameter values of the associated picture elements should be transformed to the colour reproduction space of the colour printing unit 7. This can be done by "clipping" the parameter values, the transformation being so effected that the parameter values obtainable are situated on the envelope of the said colour reproduction space. Instead of clipping, it is also possible to compress colour parameter values, although this has adverse effects, for example in the case of the repeated copying of generation copies, and which are also related to the position of the uncertainty area 2. The said transformation takes place in unit 19. Of course the parameter values originally situated outside the en-

veloping edge will without difficulty be given a pertinent indication of colour behaviour, and this need not be discussed further in connection with tracing and eliminating register errors. The transformed parameter values can be fed directly with the associated indication to a unit 13 in which the usual picture processing steps, such as UCR and half toning, and determination of control data for the colour printing unit 7, take place.

The picture elements are then fed successively to a unit 10 in which the picture elements with colour parameter values not subjected to the said transformation in unit 19 are subjected to the algorithm for the elimination of register errors.

The picture elements which as a result of this algorithm have been given a chroma value 0 in unit 10 are no longer tested by analysis into colour behaviour or colourless behaviour. The colourless label of such a picture element is made directly available to unit 11 for the post-processing algorithm. The L, C and H values originally associated with that picture element are indeed fed to a unit 12 for analysis of colour behaviour or colourless behaviour, since these values may still be of importance to investigation at neighbouring picture elements. In unit 12 the picture elements to be investigated are subjected to analysis to determine a pertinent indication concerning colourless or colour behaviour. Each picture element which has not yet been given a colourless label with chroma value 0 on the basis of the edge black replacement algorithm is here given a label regarding the pertinent indication of colourless behaviour or colour behaviour. In other words, a picture element is only assigned a pertinent indication of colourless behaviour to replace any other pertinent indication if such picture element has at least one pertinent indication which is colourless.

Each picture element is then offered to unit 11 for the post-processing algorithm either with the colourless label obtained by unit 10 or with a label obtained by unit 12, and a number of labels having the indication of colour behaviour are corrected to that of colourless behaviour. Of course each picture element having a colourless label assigned also receives a chroma value or saturation value of 0. After a label indicating a colour or colourless behaviour has been assigned to each picture element, further processing on the picture elements, e.g. UCR and half toning, and the determination of control data as required and conventional for the colour printing unit 7, can take place in the unit 13 connected to unit 11.

Of course, for the purpose of the processing operations on raster picture elements or for determining control data, which take place in the units of the picture processing and control unit 6, the buffer memory means required for those rasters are

present in those units. It is also permissible to operate the post-processing algorithm with half the resolution so that in fact a simplified calculation is obtained for the algorithm.

It is not necessary to perform the process steps in sequence as shown in Fig. 4. A more practical approach of the process events is obtained if a number of process steps are performed independently of one another and to some extent simultaneously as shown in the picture processing and control unit illustrated in Fig. 5. Thus labelling according to the algorithm for the elimination of register errors in unit 10, determination of a colour label, colourless label or provisional label for undefined colour behaviour in unit 14, and the "hue test" analysis in unit 15 can take place as parallel processes. A unit 16 receives and processes the results of the data to be supplied by units 14 and 15, in such manner that the data element of unit 14 is maintained if it relates to a colour label or colourless label, but when it relates to a provisional label with undefined colour behaviour the result of unit 15 is taken over as a substituent data element. A unit 17 receives the data from units 10 and 16 and replaces a pertinent colour behaviour label delivered by unit 16 by a pertinent colourless behaviour label only if unit 10 detects that the associated picture element must be colourless. A unit 18 is also present which for the purpose of the unit 11 operating in accordance with the post-processing algorithm is adapted to investigate the condition:

$$(\Delta L)_{\max} \geq g$$

in respect of a given picture element in an added raster, or the alternative criterion already mentioned in this connection. The result of this test together with the result of unit 17 is fed to unit 11, which operates in accordance with the post-processing algorithm, in which for each picture element the final result is determined in respect of a colour label or colourless label.

The data delivered by unit 11 are then corrected and processed in unit 13 to give control signals for controlling a colour printing unit 7. The units not referred to in connection with this Figure have a corresponding operation to those indicated by the same reference numeral in Fig. 4.

Some methods of processing picture information in accordance with the principle of the invention deliver such good results that it is permissible to omit the post-processing algorithm. In that case unit 11 acts as a kind of combination circuit which always allows an indication of colourless behaviour generated by unit 10 to pass, and, in the event of unit 10 not generating such indication, unit 11 allows the result of processing in unit 12 to pass.

The invention has been described above by refer-

ence to the LCH colour space. However, of course, the principle of the invention is not restricted to this colour space, but is also applicable to colour spaces defined by parameters related to the parameters of the LCH colour space.

The principle of the invention has been described by reference to a single LC sub-space, and this is independent of the actual H value of a picture element to be examined. Perceptual observations show that a refinement of the invention in respect of the LC test is obtained by performing this LC test in colour-dependent manner. From practical considerations, however, it is impracticable to provide for each hue value a separate LC sub-space with an adapted distribution of the sub-space into the three areas. Instead, an LC sub-space for each hue value with an adapted distribution of that sub-space in the three areas is created for a number (n) of specific hue values. A separate Fig. 1 or Fig. 2 can then be added to each of these LC sub-spaces, in which the lines l_1 to l_8 occur with associated specific parameters. An applicable value could now be: $n = 16$. With regard to assigning one of the types of indications, a Figure of this kind not only governs the associated hue value but also picture elements with hue values situated in an area around such a specific hue value. In performing an LC test for a certain picture element it is necessary first to establish the hue area that that picture element belongs to and hence which LC sub-space is applicable to that picture element. The associated indication in respect of any colour behaviour or the colour fulfilment degree must then be determined from the associated Fig. 1 or Fig. 2. This is possible, for example, by means of a look up table which delivers the associated indication or colour fulfilment degree to an LCH combination to be supplied.

It is also possible to apply the principle of the invention to an open colour copying system in which picture information is transmitted from one or more external signal sources via a transmission system to the picture processing and control unit 6 of a colour printing unit 7. In Figs. 4 and 5, unit 5 then acts as the said signal source. If the signal source delivers the picture information in the required colour system, the LCH system in this case, the colour conversion to be performed by units 8 and 9 by reference to a (white point) reference value should be carried out beside the said signal source 5. If the picture processing and control unit 6 receives picture element information for each picture element comprising in addition to the associated colour parameter values just a pertinent indication (or label) regarding a colour behaviour or colourless behaviour, then the picture element should be tested, on the receiving side of the picture processing and control unit, for any possi-

ble occurrence in the uncertainty area, in order to assign the picture element a provisional indication regarding an undefined

colour behaviour instead of the pertinent indication obtained.

For this purpose, the picture processing and control unit should be provided with at least the following:

- memory means with positional data concerning a sub-space within the colour space applied, such sub-space being considered an uncertainty area in respect of colour behaviour;
- selection means for selecting a picture element having positional data within the said uncertainty area by means of the said memory means;
- means for performing an environmental analysis concerning the distribution state of parameter values related to the said colour space in respect of picture elements occurring within a defined environment of the said picture element; and
- means for assigning a pertinent indication on the basis of the results of the environmental analysis performed in respect of the said picture element

Claims

1. A method of assigning a pertinent indication in respect of colour behaviour to a picture element to be imaged with a colour reproduction system, the method being characterised by:
 - a. locating the said picture element - on the basis of at least the parameter values of the said picture element related to colour saturation and intensity - with respect to a defined sub-space within a colour space, such sub-space being considered as an uncertainty area in respect of colour behaviour, the said colour space being defined by at least the parameters of the said type;
 - b. performing - in respect of the said picture element upon locating in the said uncertainty area - an environmental analysis concerning the distribution state of parameter values, related to the said colour space, of picture elements occurring within an environment of the associated picture element; and
 - c. assigning a pertinent indication to the said picture element on the basis of the said environmental analysis.
2. A method according to claim 1, characterised in that the said picture element upon locating in the said uncertainty area is assigned a per-

- tinent indication of colour behaviour if the relative distribution state of the parameter values related to colour in respect of the picture elements occurring in the said environment remains within predetermined limits. 5
3. A method according to claim 1, characterised in that the said picture element upon locating in the said uncertainty area is assigned a pertinent indication of colour behaviour if the average value of the parameter values related to colour saturation for the picture elements occurring in the said environment exceeds a certain threshold. 10
4. A method according to claim 1, characterised in that the said picture element upon locating in the said uncertainty area is assigned a pertinent indication of colour behaviour if both the relative distribution state of the parameter values related to colour in respect of the picture elements occurring in the said environment remains within predetermined limits and the average value of the parameter values related to colour saturation in respect of picture elements occurring in the said environment exceeds a certain threshold. 15 20 25
5. A method according to claim 1, characterised in that the said picture element upon locating in the said uncertainty area is assigned a colour fulfilment degree which represents the expectation value of a picture element in respect of colour behaviour. 30 35
6. A method according to claim 5, characterised in that a picture element upon locating in the said uncertainty area is given a specific pertinent indication if the colour fulfilment degree of the associated picture element increased by a fraction of the average value of the fulfilment degree in said environment and after normalization of the result thus obtained is situated in the value area added to that specific pertinent indication. 40 45
7. A method according to claim 5, characterised in that a picture element upon locating in the said uncertainty area is given a specific pertinent indication if the average value of the fulfilment degree in said environment is situated in the value area added to that specific pertinent indication. 50
8. A method according to claim 5, characterised in that the environmental analysis is only based on picture elements to which a partial colour fulfilment degree is assigned. 55
9. A method according to claim 5, characterised in that the colour fulfilment degree is represented by an angle information to be determined in the LC colour sub-space associated with a straight line passing through the coordinate pair in said space representing the picture element and a predefined point in that space.
10. A method of assigning a pertinent indication in respect of colour behaviour to a picture element to be imaged with a colour reproduction system, the method being characterised by:
- a. testing the said picture element for situation with respect to a text edge;
 - b. assigning a pertinent indication concerning colourless behaviour if the situation of said picture element complies with that of a text edge;
 - c. locating the said picture element - on the basis of at least the parameter values of the said picture element related to colour saturation and intensity - with respect to a defined sub-space within a colour space, such sub-space being considered as an uncertainty area in respect of colour behaviour, the said colour space being defined by at least the parameters of the said type;
 - d. performing - in respect of the said picture element upon locating in the said uncertainty area - an environmental analysis concerning the distribution state of parameter values, related to the said colour space, of picture elements occurring within an environment of the associated picture element;
 - e. assigning a pertinent indication to the said picture element on the basis of the results of the said environmental analysis; and
 - f. assigning a single pertinent indication of colourless behaviour to the said picture element as a substitute for any other pertinent indication only if the said picture element has at least one pertinent indication which is colourless.
11. A method of assigning a pertinent indication in respect of colour behaviour to a picture element to be imaged with a colour reproduction system, the method being characterised by:
- a. testing the said picture element for situation with respect to a text edge;
 - b. assigning a pertinent indication concerning colourless behaviour if the situation of said picture element complies with that of a text edge;
 - c. in the event of a pertinent indication not being assigned to the said picture element, locating the said picture element - on the

- basis of at least the parameter values of the said picture element related to colour saturation and intensity - with respect to a defined sub-space within a colour space, such sub-space being considered as an uncertainty area in respect of colour behaviour, the said colour space being defined by at least the parameters of the said type; 5
- d. performing - in respect of the said picture element upon locating in the said uncertainty area - an environmental analysis concerning the distribution state of parameter values, related to the said colour space, of picture elements occurring within an environment of the associated picture element; 10
- and 15
- e. assigning a pertinent indication to the said picture element on the basis of the results of the said environmental analysis. 20
- 12.** A method according to claim 10 or 11, characterised in that the situation of the said picture element complies with that of a text edge if the said picture element forms part of a edge having a high brightness transition and is situated in an area of picture elements of low colour saturation. 25
- 13.** A method according to claim 10 or 11, characterised in that a pertinent indication of colour behaviour is changed by an indication of colourless behaviour if, in a defined environment of the picture element, the number of picture elements having a pertinent indication of colour behaviour is below a certain value. 30
- 14.** A method according to claim 1, 10 or 11, characterised in that determination of an indication of the said type in respect of a picture element is effected by reference to parameter values associated with such picture element and related to colour value, colour saturation and intensity. 40
- 15.** A method according to claim 1, 10 or 11, characterised in that in locating the said picture element in the said colour space in respect of said picture element a choice is made from: 45
- a provisional indication concerning an undefined colour behaviour of a picture element if such picture element is situated in the said uncertainty area within the said colour space; 50
 - a pertinent indication of colour behaviour of a picture element if such picture element is situated in a second area within the said colour space; and 55
- a pertinent indication concerning a colourless behaviour of a picture element if such picture element is situated in a third area within the said colour space.
- 16.** A colour reproduction system provided with means for generating colour information point by point, and provided with a picture processing and control unit for correcting and processing this colour information to give control signals for controlling a colour printing unit, said picture processing and control unit being adapted to assign a pertinent indication in respect of colour behaviour to a picture element, characterised in that the colour reproduction system is for this purpose provided with:
- a. memory means with positional data concerning a defined sub-space within a colour space, such sub-space being considered an uncertainty area in respect of colour behaviour, the said colour space being defined at least by parameters related to colour saturation and intensity;
 - b. selection means for selecting a picture element having positional data within the said uncertainty area by means of the said memory means;
 - c. means for performing an environmental analysis concerning the distribution state of parameter values related to the said colour space in respect of picture elements occurring within a defined environment of the said picture element; and
 - d. means for assigning a pertinent indication on the basis of the results of the environmental analysis performed in respect of the said picture element.
- 17.** A colour reproduction system provided with a colour scanning unit for scanning an original point by point and generating associated colour information, and provided with a picture processing and control unit for correcting and processing this colour information to give control signals for controlling a colour printing unit, said picture processing and control unit being adapted to assign a pertinent indication in respect of colour behaviour to a picture element, characterised in that the colour reproduction system is for this purpose provided with:
- a. memory means with information concerning an indication of the occurrence of colour at a picture element in a colour space defined by at least the parameters related to colour saturation and intensity, the following being distinguished in said memory means:
 - a provisional indication concerning an undefined colour behaviour of a pic-

ture element if such picture element is situated in a first area within the said colour space;

- a pertinent indication of colour behaviour of a picture element if such picture element is situated in a second area within the said colour space; and 5
- a pertinent indication of a colourless behaviour of a picture element if such picture element is situated in a third area within the said colour space; 10

b. selection means for selecting from the said memory means an indication concerning the occurrence of colour in respect of each picture element on the basis of at least the associated parameter values of the said type and assigning such indication to the said picture element; 15

c. means for performing an environmental analysis concerning the distribution state of parameter values related to the said colour space in respect of picture elements occurring within a defined environment of the said picture element; and 20

d. means for converting to a pertinent indication the provisional indication associated with the said picture element as obtained on the basis of the results of the environmental analysis performed in the case of the said picture element with the provisional indication. 25 30

colour in respect of a picture element.

18. A colour reproduction system according to claim 16 or 17, characterised in that the said means are provided with comparison means for selecting, in a defined environment, the maximum parameter value related to colour and the minimum colour parameter value and calculating the difference between the two colour-related parameter values, and means for calculating the average colour saturation value in the associated environment. 35 40

19. A colour reproduction system according to claim 16 or 17, characterised in that the colour reproduction system for a plurality of colour values is provided with different memory means with information on an indication concerning the occurrence of colour in respect of a picture element. 45 50

20. A colour reproduction system according to claim 19, characterised in that the colour reproduction system is provided with means whereby, by reference to a colour value added to a picture element, memory means are assigned and selected which contain information on an indication concerning the occurrence of 55

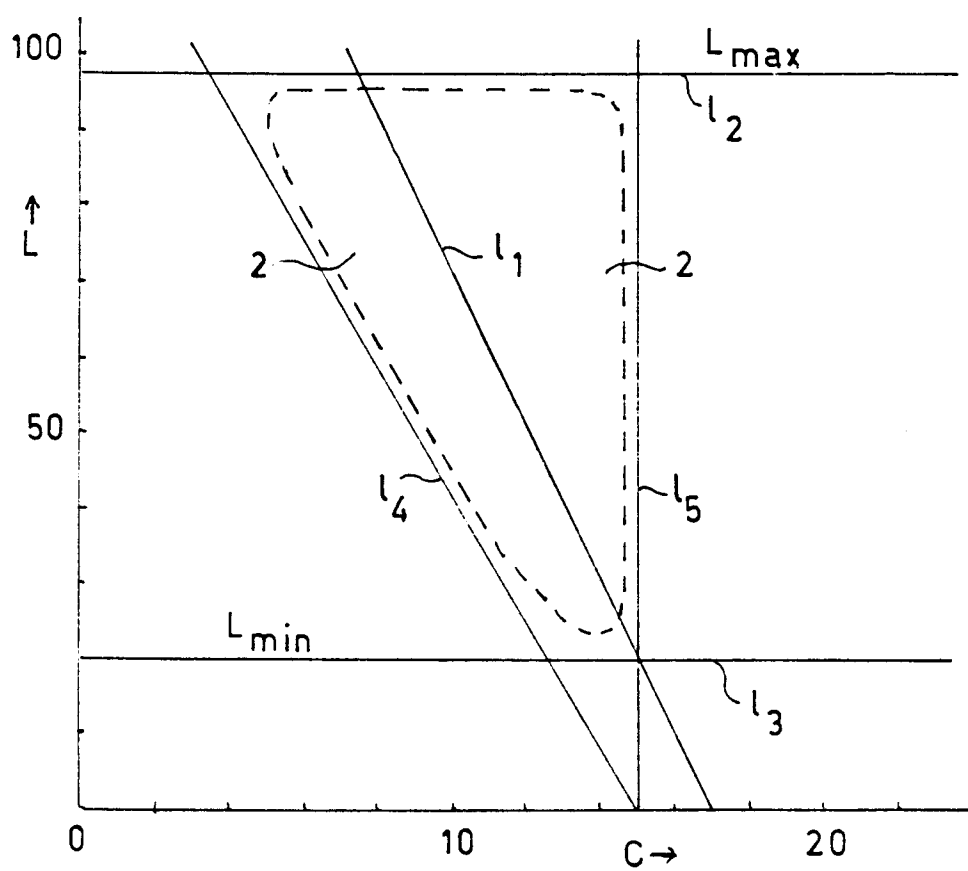


Fig. 1

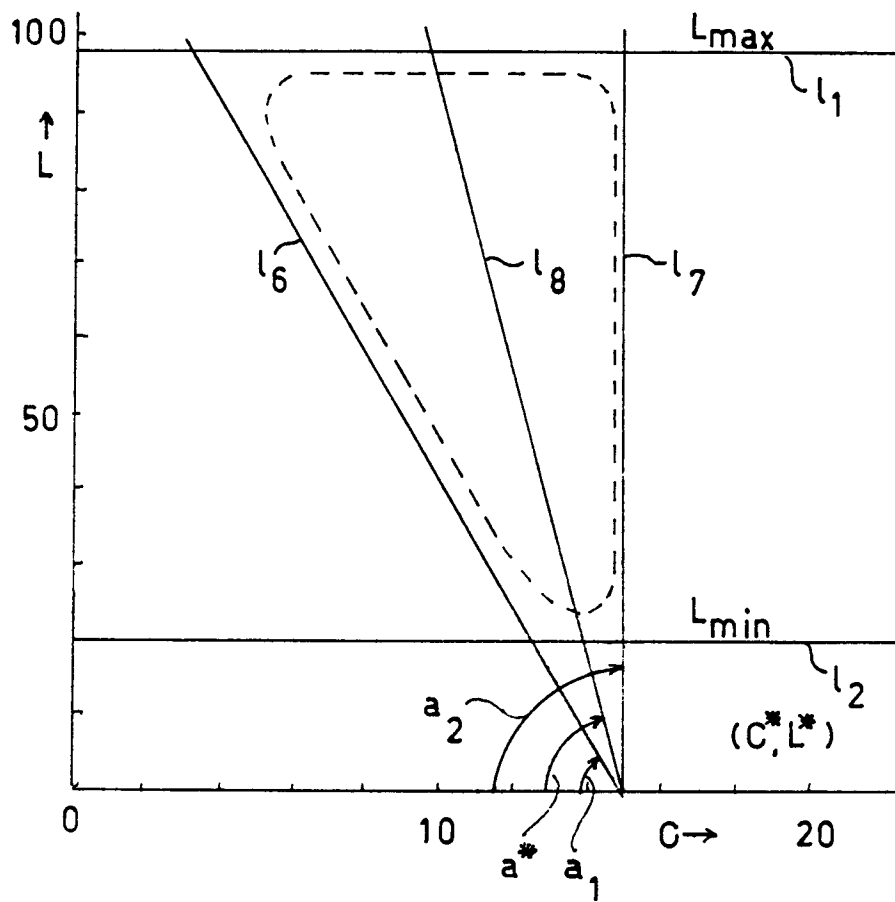


Fig.2

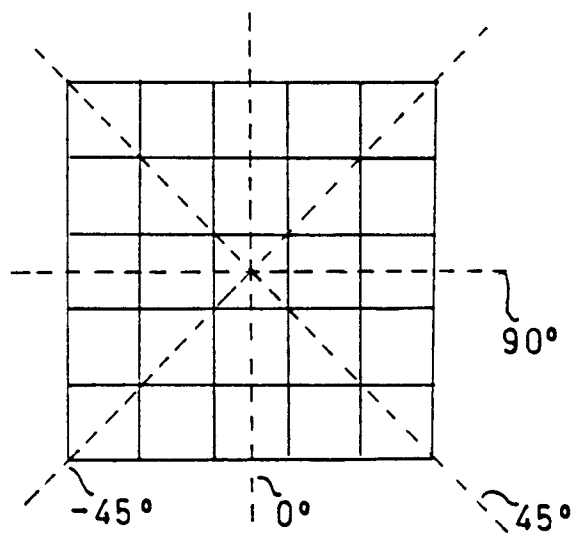


Fig.3

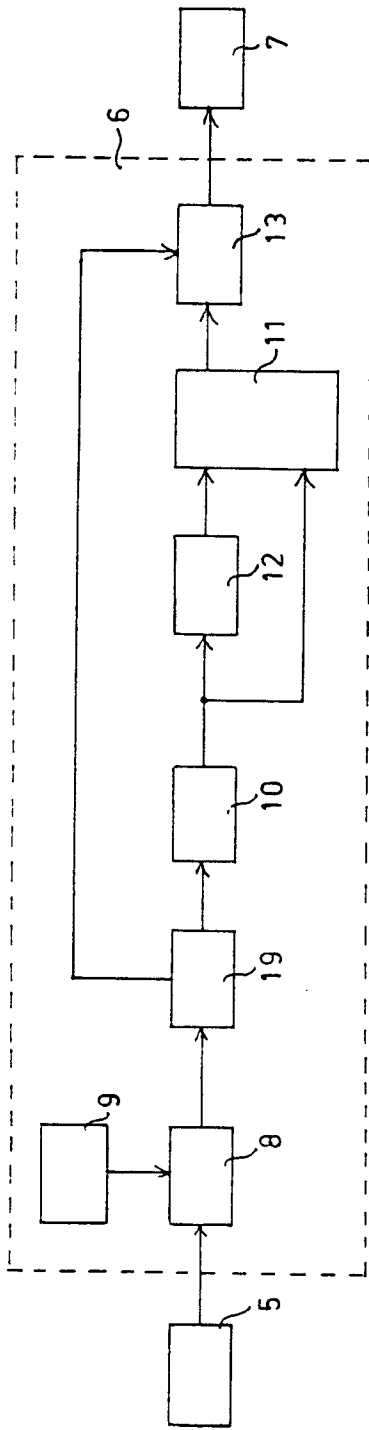


Fig. 4

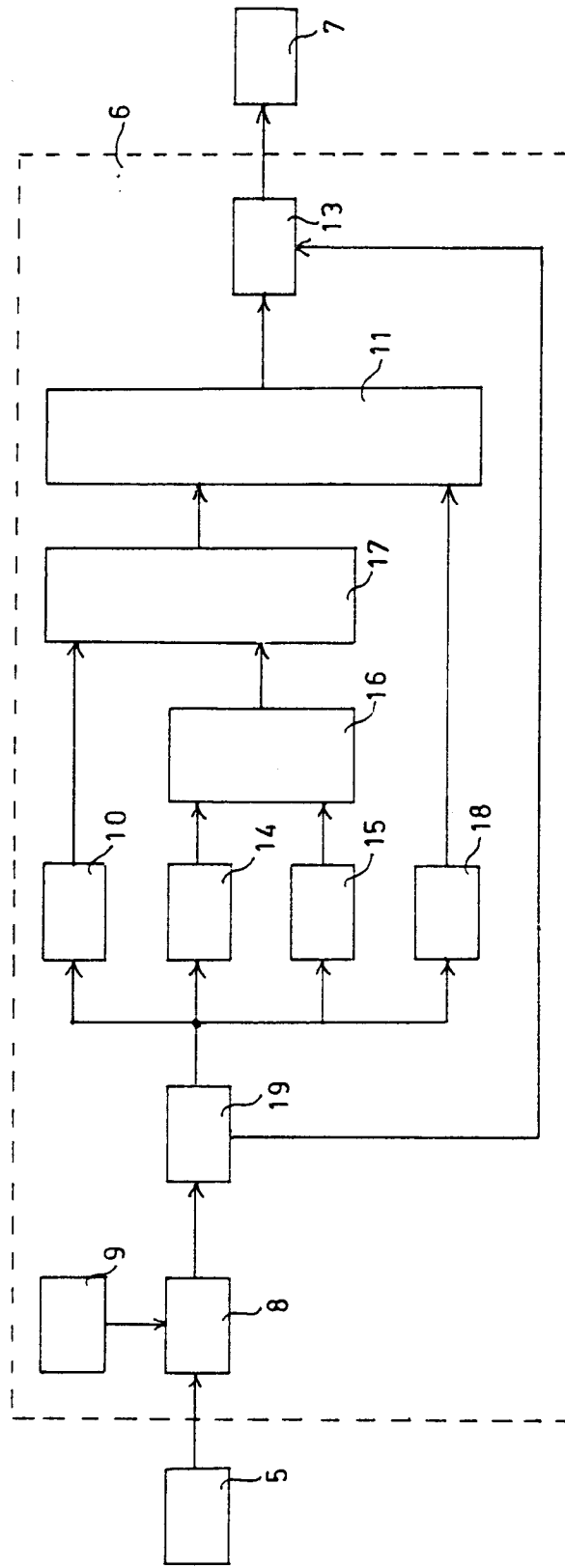


Fig. 5



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 93 20 2799

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
D,Y A	EP-A-0 363 146 (CANON K.K.) * page 14, line 14 - page 15, line 13 * * page 16, line 50 - page 19, line 29 * * page 20, line 19 - page 21, line 27 * ---	1,3,10, 12,13, 15-18 2,4,11, 14	H04N1/46
D,Y A	EP-A-0 395 032 (KONICA CORPORATION) * page 4, line 14 - page 5, line 30 * ---	1,3,10, 12,13, 15-18 2,4,5,11	
A	US-A-4 841 361 (M. MATSUNAWA ET AL.) * column 7, line 50 - column 8, line 45 * -----	15	
			TECHNICAL FIELDS SEARCHED (Int.Cl.5)
			H04N
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 3 December 1993	Examiner De Roeck, A
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application I : document cited for other reasons & : member of the same patent family, corresponding document			